Testimony of

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Before the

Energy and Technology Committee

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Regarding

Proposed H.B. No. 6021 - An Act Concerning Test Bed Technologies

Introduction

The Connecticut Center for Advanced Technology, Inc. ("CCAT"), offers this testimony in support of Proposed House Bill. No. 6021 - An Act Concerning Test Bed Technologies.

CCAT is a nonprofit corporation that provides services and resources to entrepreneurs, businesses, industry, academia, and government. The Energy Initiative of CCAT has been established to improve the economic competitiveness of the region through solutions that lower energy costs and increase long-term energy reliability. This CCAT Initiative also provides assistance to businesses and manufacturers regarding energy use and energy efficiency; promotes use of sustainable and renewable energy; and undertakes energy planning, including regional planning for zero emission vehicle (ZEV) deployment.

CCAT supports the concept to have state agencies cooperate in an effort to locate, test and procure safe and efficient energy technologies for state agency use. In particular, CCAT suggests that there should be a focus on efficient energy technologies developed and manufactured in the State.

In conjunction with this effort to advance efficient energy technologies, CCAT has developed a Connecticut state "Roadmap" for hydrogen and fuel cell technology, and a regional (ME TO NJ) plan for ZEV deployment. The "Roadmap" was developed through extensive market research and technical assessment to encourage the deployment of efficient energy technologies for hydrogen production and fuel cell powered generation. Fuel cells have an overall efficiency of 85 to 93 percent when used to provide both heat and power, and is defined as a Class I renewable source. Applications for deployment for State use, include universities, institutions, training facilities, correctional facilities, office buildings, transportation facilities, pollution control, telecommunications, airports, etc. This technology is being developed and manufactured here in the State, which supports over 1,000 jobs and revenues of over $600 million per year. The Roadmap document (attached) provides detailed information on the technology, economic impact, market targets, and supportive policies. CCAT has concluded that 119-158 megawatts of fuel cell combined heat and power capacity is economically and technically possible to meet state policy for clean and efficient energy production at all potential sites.

The regional ZEV plan is currently in development with assistance from the U.S. Small Business Administration and U.S. Department of Energy supported H2USA initiative. This regional plan identifies market opportunities for ZEV and hydrogen refueling infrastructure to support the ZEVs. Hydrogen production infrastructure technology manufactured in Connecticut is expected to play a significant role to fuel ZEV to be deployed at private and state-owned fleets to meet the Eight-State MOU (CT, CA, OR, MA, NY, MD, RI, VT). CCAT has concluded that 477 fuel cell fuel cell electric vehicles and 4-5 hydrogen refueling stations would be appropriate Connecticut goals for clean and efficient transportation and to ensure compliance with the Eight-State MOU.

Conclusion

CCAT is supportive of the concept to evaluate and procure efficient energy technologies, products, or processes for use by any or all state agencies. Key products, which are manufactured in Connecticut, will be fuel cells for combined heat and power at state facilities and hydrogen refueling at state transportation and fleet facilities.

CCAT will make itself available to the Committee and legislature upon request to assist in the refinement of this legislation.

Respectfully submitted,

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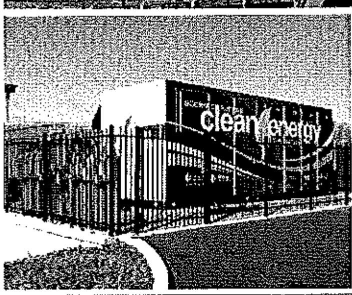
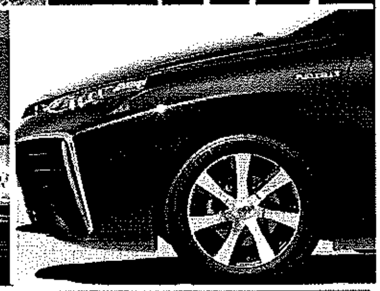
Director of Energy Initiatives

2015 Hydrogen & Fuel Cell Development Plan





Connecticut - Hydrogen Economy

- Economic Development
- Environmental Performance
- Energy Reliability

Northeast Electrochemical energy storage Cluster

Hydrogen and Fuel Cell Development Plan – "Roadmap" Collaborative Participants

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Supporting Agencies
United States Small Business Administration[1]

Supporting Organizations
Connecticut Center for Advanced Technology Inc. (CCAT)
Clean Energy Finance and Investment Authority (CEFIA)

Special thanks to the U.S. Department of Energy for peer reviewing this document

Northeast Electrochemical energy storage Cluster

Cover Photo References
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Connecticut Center For Advanced Technology; "UConn Fuel Cell," Alexander Barton; November 2012.

FuelCell Energy Inc.; "Dominion Bridgeport Fuel Cell;' August, 2014.

Sunhydro; "Hydrogen Powered Cars;" http://www.sunhydro.com/; October 2011.

Toyota; "Introducing Toyota Mirai;" http://www.toyota.com/fuelcell/fcv.html; February 2015

[1] This document was produced with support and assistance from the United States Small Business Administration

Table of Contents

Executive Summary 3
Introduction 4
Drivers 5
Policy 5
Economic Impact 5
Stationary Power 7
Transportation 9
Conclusion 13

Index Of Figures

Figure 1 – Fuel Cell Operation 4

Index Of Tables

Table 1 – CT Hydrogen Fuel Cell Policy Incentives 5
Table 2 – Connecticut Economic Data – Hydrogen Fuel Cell Industry 6
Table 3 – Fuel Cell System Advantages 7
Table 4 – Stationary Targets 7
Table 5 – Policy/Incentives for Stationary Fuel Cell Development 8
Table 6 – Transportation Targets 9
Table 7 – FCEV Advantages 9
Table 8 – FC Material Handler Advantage 11
Table 9 – Policy/Incentives for FCEV Deployment 12

EXECUTIVE SUMMARY

Existing Connecticut businesses and institutions have the potential to install up to **131 to 175 megawatts (MW)** of electric generation and combined heat and power (CHP) using fuel cell technology. With an annual output of **912,135 – 1,211,000 megawatt hours (MWhs)**, these fuel cell generation facilities can reduce carbon dioxide (CO_2) emissions by between **277,000 – 368,000 tons** annually.

Zero emission fuel cell electric vehicles (FCEV) could replace existing conventional vehicles in Connecticut, starting with **477 vehicles**, which can reduce annual CO_2 emissions by approximately **4,200 to 7,300 tons** per year. Additionally, fuel cells could provide a zero emission alternative for fork lifts and other material handling equipment necessary for prolonged work in enclosed warehouse space.

While fuel cell installation/deployment may be technically viable at many locations, this plan focuses on hydrogen and fuel cell applications that are both technically and economically viable. The Northeast Electrochemical Energy Storage Cluster (NEESC) has recommended the following goals for stationary and transportation hydrogen fuel cell deployment to meet economic, environmental, and energy needs:

- **131 to 175 MW fuel cell electric generation by 2025**
- **477 FCEVs (445 [40 FCEVs for CT State fleet] passenger and 32 transit/paratransit buses) as zero emission vehicles (ZEV)**
- **4 to 5 hydrogen refueling stations (to support FCEV deployment)**

Locations where fuel cell installations are both technically and economically viable include a wide range of private, state, and federal buildings used for offices, manufacturing, data management, warehousing, education, food sales and services, lodging, in-patient healthcare, and public order and safety. Similarly, fuel cell installations are viable at wastewater treatment plants, landfills, telecommunications sites, seaports, high-traffic airports, and for electric grid service. Locations for FCEVs and hydrogen refueling would be technically and economically viable in urban regions of the state where fleets, early market adopters, and hydrogen producers exist.

Currently, Connecticut has at least **600 companies** that are part of the growing hydrogen and fuel cell industry supply chain in the Northeast region. The age distribution of hydrogen and fuel cell companies in the Northeast suggests a substantial expansion in the sector, with several small businesses exhibiting recent growth. Growth of hydrogen and fuel cell patents in the Northeast far exceeds the growth of all types of clean energy patents in the region. Based on an IMPLAN economic analysis, these companies are estimated to have realized approximately **$604.34 million in revenue and investment**, contributed more than **$22 million in state and local tax revenue**, and generated over **$211.23 million in gross state product** from their participation in this regional energy cluster in 2011. Additionally, eight (8) of these companies are original equipment manufacturers (OEMs) of hydrogen and/or fuel cell systems, and were responsible for supplying **1,010 direct jobs and $311.65 million in direct revenue and investment** in 2011.

The deployment of hydrogen and fuel cell technology will reduce the state's dependency on oil, improve air and water quality, meet carbon and ZEV requirements, utilize renewable energy from indigenous sources such as biomass, wind, and photovoltaic (PV) power, and increase the number of energy sector jobs within the state. This plan provides links to relevant information to help assess, plan, and initiate hydrogen and/or fuel cell deployment to help meet the energy, economic, and environmental goals of the State of Connecticut.

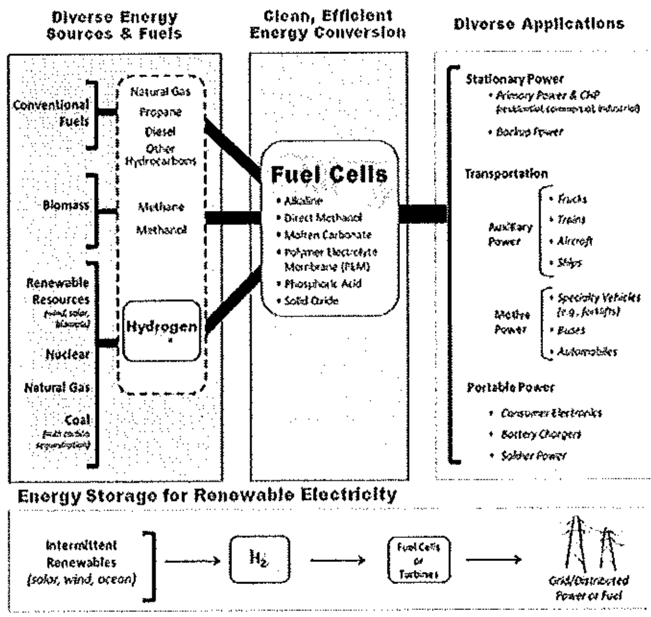
Policies and incentives that support hydrogen and fuel cell technology will increase deployment. Increased demand for hydrogen and fuel cell deployment will increase production and create jobs throughout the supply chain. As deployment increases, manufacturing costs will decline and hydrogen and fuel cell technology will be in a position to compete more effectively in a global market without support on incentives. Policies and incentives can be coordinated regionally to maintain the regional cluster as a global exporter for long-term growth and economic development.

INTRODUCTION

A 2015 *Hydrogen and Fuel Cell Development Plan* was created for each state in the Northeast region (Connecticut, Vermont, New Hampshire, Massachusetts, Rhode Island, Maine, New York, and New Jersey), with support from the United States (U.S.) Small Business Administration (SBA), to increase awareness and facilitate the deployment of hydrogen and fuel cell technology. The intent of this guidance document is to make available information regarding the economic value and deployment opportunities to increase environmental performance and energy reliability using hydrogen and fuel cell technologies.[2]

A fuel cell is a device that uses, but does not burn, hydrogen (or a hydrogen-rich fuel such as domestic natural gas) and oxygen to create an electric current. Fuel cells occupy a technology platform that when coupled with electric drivetrains have the potential to replace the internal combustion engine (ICE) in vehicles and provide power for stationary and portable power applications. Fuel cells are in commercial service throughout the world, providing thermal energy and electricity to power the grid, homes, and businesses. Fuel cells are also used in vehicles, such as forklifts, automobiles, trucks, buses, and other land, marine, air, and space equipment. Fuel cells for portable applications currently in development will provide power for video cameras, military electronics, laptop computers, and cell phones.

Figure 1 – Fuel Cell Operation[5]



Hydrogen can be produced using a wide variety of resources found here in the U.S. Hydrogen can be renewable and produced by waste, biomass, wind, solar, tidal, wave, and geothermal. Production technology includes electrolysis of water, steam reforming of natural gas, coal gasification, thermochemical production, and biological gasification.[3]

Natural gas, which is composed of four (4) hydrogen atoms and one (1) carbon atom (CH_4), has the highest hydrogen-to-carbon ratio of any energy source.[4] Furthermore, natural gas is widely available throughout the Northeast region, is relatively inexpensive, and is primarily a domestic energy supply. Consequently, natural gas shows potential to serve as a transitional fuel for the near future hydrogen economy.[5] Over the long term, hydrogen production from natural gas may be augmented with renewable energy, nuclear, coal (with carbon capture and storage), and other low-carbon domestic energy resources.[6]

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[2] This plan was developed in coordination with H_2USA and Northeast States for Coordinated Air Use Management (NESCAUM) to advance ZEV development.

[3] Hydrogentrade.com; "Hydrogen Production;" http://www.hydrogentrade.com/production/; October 2014.

[4] Go With Natural Gas; "Natural Gas and Hydrogen;" http://www.gowithnaturalgas.ca/operating-with-natural-gas/fuel/natural-gas-as-an-energy-source/natural-gas-and-hydrogen/; February 2014.

[5] EIA,"Commercial Sector Energy Price Estimates, 2009", http://www.eia.gov/state/seds/hf.jsp?incfile=sep_sum/html/sum_pr_com.html, August 2011.

[6] DOE EERE; "Hydrogen Production;" https://www1.eere.energy.gov/hydrogenandfuelcells/production/natural_gas.html; February 2014.

DRIVERS

The Northeast hydrogen and fuel cell industry, while still emerging, currently has an economic impact exceeding $1 billion in total revenue and investment. Connecticut benefits from impacts of direct, indirect, and induced employment and revenue from this industry. Furthermore, Connecticut has a definitive and attractive economic development opportunity to greatly increase its participation in the hydrogen and fuel cell industry as this collective industry strives to meet global demand for clean, low carbon heat, and power. Connecticut's biomass, wind, and photovoltaic (PV) power production initiatives could be further enhanced with energy storage provided by hydrogen. These drivers will become more important as users turn to sustainable energy sources in place of fossil fuels.

POLICY

Connecticut's relative proximity to major load centers, the high cost of electricity, concerns over regional air quality, available federal tax incentives, and legislative policy have resulted in renewed interest in the development of efficient and cost effective renewable energy. Specific policies in Connecticut supporting the hydrogen and fuel cell industry are displayed in Table 1.[7]

Table 1 – CT Hydrogen Fuel Cell Policy Incentives

- Mandatory Renewable Portfolio Standards (RPS)
- Interconnection Standards
- Net Metering
- Public Benefits Funds
- Performance-Based Power Purchase
- State Grant Programs
- State Loan Programs
- Sales Tax Incentives
- Property-Assessed Clean Energy (PACE) Financing
- Renewable Greenhouse Gas Initiative

Legislation and policy to support hydrogen and fuel cell technologies can be cost effective and appropriate for public investment. For example, Commercial Property Assessed Clean Energy (C-PACE) is an innovative program that provides affordable, long-term financing, while reducing out-of-pocket cost to building owners for smart energy efficiency and clean energy upgrades (see Appendix II for more information). The public value of the hydrogen and fuel cell industry in the Northeast region includes jobs, environmental quality, and economic development.

ECONOMIC IMPACT[8]

Connecticut is home to at least 600 companies that are part of the growing hydrogen and fuel cell industry cluster in the Northeast region. Realizing approximately $604 million in revenue and investment in 2011, these companies include manufacturing, parts distributing, fuel processing, supplying of industrial gas, engineering based research and development (R&D), coating applications, and managing of venture capital funds. [9], Furthermore, the hydrogen and fuel cell industry is estimated to have contributed approximately $22 million in state and local tax revenue, and over $211 million in gross state product annually (for 2011). Additionally, eight (8) of these companies are original equipment manufacturers (OEMs) of hydrogen and/or fuel cell systems, and were responsible for supplying 1,010 direct jobs and $311.65 million in direct revenue and investment in 2011. Table 2 shows Connecticut's impact in the Northeast region's hydrogen and fuel cell industry as of August 2011.[10]

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[7] NEESC; "Renewable Energy Incentives;" http://neesc.org/opportunities/incentives; September 2014.

[8] Economic Impact derived from an IMPLAN Economic Financial Model, Todd Gabe, August 2012.

[9] Northeast Electrochemical Energy Storage Cluster Supply Chain Database, http://neesc.org/resources/?type=1, April 8, 2014.

[10] Doosan Corporation has recently acquired ClearEdge Power Inc., which acquired UTC Power. At this time it is expected that all jobs and production facilities in South Windsor, CT will remain intact and viable.

Table 2 – Connecticut Economic Data – Hydrogen Fuel Cell Industry

	Connecticut Economic Data
Supply Chain Members	600
Gross State Product ($M)	211
State Local Tax ($M)	22
Direct Rev ($M)	311.65
Direct Jobs	1,010
Direct Labor Income ($M)	100.77
Indirect Rev ($M)	163.92
Indirect Jobs	819
Indirect Labor Income ($M)	64.28
Induced Revenue ($M)	128.77
Induced Jobs	864
Induced Labor Income ($M)	46.18
Total Revenue ($M)	604.33
Total Jobs	2,693
Total Labor Income ($M)	211.23

[11]

For every $1 million invested in fuel cell deployment in Connecticut, 19 direct and 50 indirect/induced jobs are created. [12, 13] The growth of jobs in the production of hydrogen vehicles and other hydrogen equipment may produce some job declines in traditional activities; however, there will be a net increase in job creation. Connecticut employment in the hydrogen fuel cell supply chain is predicted to increase by 700 to 2,300 jobs by 2020.[14]

Information on the age distribution of hydrogen and fuel cell companies in the Northeast is suggestive of a substantial expansion in the sector, with recent growth of several small businesses. Growth of hydrogen and fuel cell patents in the Northeast far exceeds the growth of all types of clean energy patents in the region. Analysis of the 2010 to 2013 employment growth in the region shows that a greater percentage of incumbent businesses grew than declined, and that companies experienced an average growth rate of nine (9) percent. [15]

[11] Economic data is calculated based on 2011 data.

[12] Indirect impacts are the estimated output (i.e., revenue), employment and labor income in other business (i.e., not-OEMs) that are associated with the purchases made by hydrogen and fuel cell OEMs, as well as other companies in the sector's supply chain. Induced impacts are the estimated output, employment and labor income in other businesses (i.e., non-OEMs) that are associated with the purchases by workers related to the hydrogen and fuel cell industry.

[13] DECD/ CCEF/Navigant; CT Renewable Energy/Energy Efficiency Economy Baseline Study; page 62 "Job-years Created Per $1 Million Invested;" http://www.ct.gov/deep/lib/deep/air/siprac/2009/ccef_presentation_-_05-14-09.pdf; March 27, 2009.

[14] U.S. DOE; "Effects of a Transition to a Hydrogen Economy on Employment in the United States Report to Congress;" Page 29; http://www.hydrogen.energy.gov/pdfs/epact1820_employment_study.pdf; July 2008.

[15] "Economic Profile of the Northeastern U.S. Hydrogen Energy and Fuel Cell Industry"; Todd, Gabe; April 2014.

STATIONARY POWER

In 2012, Connecticut consumed the equivalent of 145.83 million megawatt-hours (MWh) of energy from residential, industrial, and commercial sectors. Overall electricity demand is forecasted to grow at a rate of 1.1 percent annually over the next decade.[16]

Table 3 – Fuel Cell System Advantages

- High electric efficiency (> 40 percent)
- Overall efficiency 85 to 93 percent
- Reduction of noise
- Reduction of air pollution
- Siting is not controversial and
- Waste heat can be captured and used

This demand represents approximately 25 percent of the population in New England and 25 percent of the region's total electricity consumption. The state relies on both in-state resources and imports of power, with approximately 8,700 megawatts (MW) of total generation capacity; 27 percent of the total capacity in New England.[17] Demand for new electric capacity is expected due in part to the replacement of older less efficient base-load generation facilities.[18] Fuel cell technology has high value and opportunity (see Table 3) to meet grid needs and to replace older generation facilities with high efficiency generation located directly at the customer's site. Distributed generation will increase efficiency, improve end user reliability, provide opportunity for combined heat and power (CHP), and reduce emissions. Targets for CHP distributed generation (DG) include schools, hospitals and other mission critical facilities (see Table 4).[19]

Table 4 – Stationary Targets

- Education.
- Food Sales.
- Food Services.
- Inpatient Healthcare.
- Lodging.
- Public Order & Safety.

Based on the targets identified within this plan, there is the potential to develop up to 131 to 175 MW of stationary fuel cell generation capacity in Connecticut, which would provide the following benefits (see Appendix VI), annually:

- ***Production of approximately 912,135 to 1,211,070 MWh of electricity***[20, 21]
- ***Production of approximately 2.53 to 6.17 million MMBTUs of thermal energy***
- ***Reduction of CO_2 emissions by approximately 277,289 to 368,165 tons (electric generation only)***[22]

This plan focuses on applications for fuel cells in the 300 kilowatt (kW) to 400 kW range. However, larger fuel cells are potentially viable for grid applications and small fuel cells are potentially viable for site-specific applications such as back-up power for telecoms and grid resilience. Potential stationary targets are illustrated in Appendix I – Figure 1, "Connecticut: Potential Hydrogen and Fuel Cell Applications for Public Facilities" and Figure 2, "Connecticut: Potential Hydrogen and Fuel Cell Applications for Private Facilities."

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[16] U.S. Energy Information Administration (EIA); "Connecticut Energy Consumption by End-Use Sector, 2012"; http://www.eia.gov/state/?sid=CT#tabs-2; August 2014.

[17] FuelCell2000, "Fuel Cell Basics", www.fuelcells.org/basics/apps.html, July, 2011.

[18] ISO New England, "Connecticut 2013-1014 State Profile", http://www.iso-ne.com/nwsiss/grid_mkts/key_facts/final_ct_profile_2013-14.pdf, August, 2014.

[19] As defined by CBECS, Public Order & Safety facilities are buildings used for the preservation of law and order or public safety. Although these sites are usually described as government facilities they are referred to as commercial buildings because their similarities in energy usage with the other building sites making up the CBECS data.

[20] Calculations incorporate an 87.5% capacity factor when utilizing both electric and thermal loads provided by the system.

[21] US DOE; Medium-Scale CHP Fuel Cell System Targets; http://www.hydrogen.energy.gov/pdfs/11014_medium_scale_chp_target.pdf; September 30, 2011.

[22] Replacement of conventional fossil fuel generating capacity with methane fuel cells could reduce carbon dioxide (CO_2) emissions by between approximately 100 and 600 lb/MWh: U.S. Environmental Protection Agency (EPA), eGRID2010 Version 1.1 Year 2007 GHG Annual Output Emission Rates, Annual non-baseload output emission rates (NPCC New England); FuelCell Energy, DFC 300 Product sheet, http://www.fuelcellenergy.com/files/FCE%20300%20Product%20Sheet-lo-rez%20FINAL.pdf; Doosan Fuel Cell America, PureCell Model 400, http://www.utcpower.com/products/purecelhttp://www.doosanfuelcellamerica.com/energy/purecellmodel400system/; October, 2014.

Tri-generation

A tri-generation station incorporates CHP technology that produces hydrogen in addition to heat and electricity. Hydrogen produced by the fuel cell system can be used to support a fueling station for FCEVs or for industrial purposes. FuelCell Energy is currently involved in the manufacture of tri-generation technology and operation of a tri-generation facility that runs on natural gas and biogas. This facility produces heat and power for a wastewater treatment facility and hydrogen for vehicles.[23]

Emergency Preparedness

Recent weather events in the Northeast including Hurricane Irene (2011), the Nor'easter snowstorm (2011), Superstorm Sandy (2012), and Blizzard Nemo (2013) have emphasized the need for clean, reliable, baseload distributed generation located at mission critical facilities to maintain power when grid power is not available due to storm damage. Over 25 fuel cells, located in the Northeast region affected by Hurricane Sandy, performed as expected and provided electricity, heat, and hot water during and after the storm passed. Several states are considering initiatives that include increased use of performance and engineering standards, improved planning, hardening of the infrastructure, increased communications and collaboration, additional response training, and the use of microgrids and other emerging technologies to mitigate impact(s) on energy grid infrastructure. Fuel cells are now being considered as ultra clean generators for microgrids to reliably provide heat and electricity at base load and to operate in island mode to serve essential needs during extended power outages.

STATIONARY FUEL CELL GOALS

NEESC recommends a goal to develop 131 to 175 MW of fuel cell technology in Connecticut by 2025. This goal coupled with the existing 28.6 MW of fuel cells currently operating in Connecticut would result in a total of 159.6 to 203.6 MW of high efficiency fuel cell capacity by 2025 (See Appendix VII for installed fuel cell locations in Connecticut).

Fuel cells are already in use for buildings, data centers, telecommunications applications, power for remote locations, distributed power generation, grid resilience, and cogeneration (in which excess heat released during electricity generation is used for other applications).

Transformation requires vision, commitment, and action to overcome challenges associated with the deployment of stationary fuel cells. Continued advancement of hydrogen and fuel cell technology to advance economic, energy, and environmental policy will require the continuation of existing incentives such as, mandatory renewable portfolio standards (RPS), interconnection standards, net metering and virtual net metering, public benefits funds, cooperation and/or ownership from electric utilities, and performance based power purchase agreements (see Table 5 and Appendix V – State Energy Policy/Incentives for Stationary Fuel Cells and Hydrogen Transportation).[24]

Table 5 – Policy/Incentives for Stationary Fuel Cell Development

- Renewable Portfolio Standards
- Net Metering
- Public Benefits Funds
- Performance Power Purchase
- State Grant Programs
- State Loan Programs
- Property Tax Incentive
- Sales Tax Incentive
- Property-Assessed Clean Energy (PACE) Financing

[23] DOE, EERE; "World's First Tri-Generation Fuel Cell and Hydrogen Station;" http://apps1.eere.energy.gov/successes/success_story.cfm/news_id=19219/prog=600; September 2014.
[24] NEESC; "Renewable Energy Incentives;" http://neesc.org/opportunities/incentives; September 2014.

TRANSPORTATION

Table 6 – Transportation Targets
• Public/Private Fleets.
• Bus Transit.
• Material Handling.
• Ground Support Equip.
• Auxiliary Power Units.
• Ports.

As oil and other non-sustainable hydrocarbon energy resources become scarce, energy prices will increase and the reliability of supply will be reduced. Government and industry are now investigating the use of hydrogen and renewable energy as a replacement of hydrocarbon fuels in the transportation section, which accounts for 32 percent of Connecticut's total energy consumption.[25] As these system sizes and applications increase efficiency will increase resulting in more favorable economics and increased reliability. Targets for FCEV deployment and hydrogen infrastructure development include public/private fleets, bus transit, and specialty vehicles (see Table 6). Zero emission FCEVs could replace existing conventional fleet vehicles in Connecticut, starting with 477 vehicles, providing annual carbon dioxide (CO_2) emissions reduction of approximately 4,194 to 7,330 tons per year.[26, 27] FCEVs have advantages (see Table 7) over conventional technology and can reduce price volatility, decrease dependence on oil, improve environmental performance, and provide greater efficiencies, as follows:

Table 7 – FCEV Advantages
• Quiet operations
• Zero/Near zero emissions
• Domestic fuel supply
• Price volatility reduction
• Energy security and
• Higher efficiency

- Fuel cells can achieve 40 to 70 percent efficiency, which is substantially greater than the 30 percent efficiency of the most efficient internal combustion engines.[28]
- FCEVs running on hydrogen produced from renewable resources virtually eliminate all GHG emissions compared to conventional fossil fuel powered vehicles. Passenger car emissions of CO_2 are reduced by 4.75 metric tons CO_2E /vehicle/year.[29, 30, 31]
- Fuel cells offer significant GHG reduction opportunities for heavy duty transit buses.[32, 33] A bus powered by hydrogen fuel cell technology run completely on hydrogen from renewable resources could displace 65 to 163 metric tons CO_2E/vehicle/year of diesel bus emissions.[34]

Automakers are now making plans to comply with a ZEV program, which is modeled after the California ZEV Action Plan.[41, 42] Eight (8) states have committed and signed a Memorandum of Understanding

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[25] U.S. Energy Information Administration (EIA); "Connecticut Energy Consumption by End-Use Sector, 2012"; http://www.eia.gov/state/?sid=CT#tabs-2; August 2014.

[26] Analyses conducted by the Connecticut Center for Advanced Technology (CCAT) based on the ZEV eight-state MOU and R. L. Polk vehicle data. Eight (8) State MOU projection of 3.3 million and total 2011 registered vehicles were used to derive 4.675 percent of registered vehicles that may be registered as ZEVs. Percent calculated was then applied to fleet vehicles as a conservative early projection.

[27] CO_2 emission reduction = 4.75 metric tons CO_2E /vehicle/year*445 (FCEVs) + 65 to 163 metric tons CO_2E /vehicle/year*32 (FCEB) = 4,193.75 to 7,329.75 metric tons CO_2E /vehicle/year.

[28] EPA; "Fuel Cells & Vehicles: Basic Information;" http://www.epa.gov/fuelcell/basicinfo.htm; November, 2014.

[29] GHG emissions include carbon dioxide, methane, and nitrous oxide, all expressed as carbon dioxide equivalents.

[30] 8.89×10^{-3} metric tons CO_2/gallon gasoline × 11,318 VMT car/truck average × 1/21.4 miles per gallon car/truck average × 1 CO_2, CH_4, and N_2O/0.988 CO_2 = 4.75 metric tons CO_2E /vehicle/year.

[31] U.S. EPA; "Calculations and References;" http://www.epa.gov/cleanenergy/energy-resources/refs.html; August 9, 2014

[32] On average transit buses travel 20,000 to 50,000 miles annually, typical for major metropolitan areas.

[33] Emissions from conventional urban diesel buses range from 3,000 to 7,000 grams CO_2E/mi/year (exact figures depend upon traffic conditions and number of bus route stops).

[34] Ballard; "Fuel Cell-Powered Buses: A Cost-Benefit Perspective;" http://www.ballard.com/files/PDF/Bus/Bus_Benefits_FCvelocity.pdf; February 2012.

[41] Only the largest automakers are subject to the mandate: BMW, Daimler AG, Ford, General Motors, Honda, Hyundai, Kia, Mazda, Nissan, Toyota, and Volkswagen.

(MOU) requiring large-volume automakers to sell approximately 3.3 million ZEVs between 2018 and 2025, 1.24 million of which are defined as "ZEVs (Electric and/or Hydrogen Fuel Cells)".[43] Additionally, a 2012 Preliminary Study conducted by the National Renewable Energy Laboratory (NREL) projects deployment of approximately 117,000 to 205,000 FCEVs in the Northeast region by 2025.[44] Automakers have indicated that they plan to introduce hydrogen FCEVs by 2015.[45, 46] As one of the eight states that has signed this MOU, Connecticut has the potential of deploying approximately 80,000 FCEVs by 2025.[47] The expected result of this deployment will be high efficiency vehicles that require less fuel and produce very low or zero tailpipe emissions.[48]

Potential deployment appears very large based on the Eight (8) State MOU projection of 3.3 million ZEVs by 2025. NEESC took a more conservative approach by applying the NESCAUM projections to the total registered vehicles to derive 4.675 percent of registered vehicles that may be registered as ZEV, and then applied this percentage to fleet vehicles as a conservative early projection.[49]

Fleets

There are over 9,500 passenger fleet vehicles classified as non-leasing or company owned vehicles in Connecticut.[50] Passenger vehicles at transportation hubs are good candidates for hydrogen fueling and conversion to FCEVs because they mostly operate on fixed routes or within fixed districts and are fueled from a centralized station. As illustrated in Appendix I – Figure 3, "Connecticut: Potential Hydrogen and Fuel Cell Applications for Transportation," the fleet clusters in Connecticut are located primarily in the Bridgeport, Danbury, Hartford, New Haven, and Stamford metropolitan areas.

Bus Transit

There are approximately 670 buses that provide public transportation services in Connecticut.[51] Although the efficiency of conventional diesel buses has increased, these buses, which typically achieve fuel economy performance levels of 3.9 miles per gallon, have the greatest potential for energy savings by using high efficiency fuel cells.[52] Fuel cell buses are currently in use in several states, with many on

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[42] CA.gov; "2013 ZEV Action Plan;" http://opr.ca.gov/docs/Governor's_Office_ZEV_Action_Plan_(02-13).pdf; February 2013.
[43] Mass.gov; "State Zero-Emission Vehicle Programs: Memorandum of Understanding;" http://www.mass.gov/eea/docs/dep/air/priorities/zev-mou-final.pdf; October 24, 2013.
[44] Northeast Region includes Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, and New York.
[45] Cars.com; "Hyundai Plans Tucson Fuel-Cell for 2015;" http://blogs.cars.com/kickingtires/2013/05/hyundai-plans-tucson-fuel-cell-for-2015.html; May 20, 2013.
[46] Auto blog green; "2015 Toyota hydrogen fuel cell car will have 300-mile range;" http://gas2.org/2013/07/02/toyotas-2015-fuel-cell-car-aims-for-300-mile-range/; July 2, 2013.
[47] Derived from 8-State MOU projected deployment rates calculated for California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont.
[48] The existing hydrogen and fuel cell industry in the Northeast is comprised of almost 1,200 supply chain companies, $1.1 billion in revenue and investment, and over 5,600 full- and part-time jobs. This data does not include full contribution from the hydrogen and fuel cell transportation industry, which would increase with market deployment of FCEVs.
[49] These projections have not been peer reviewed and/or confirmed by NESCAUM.
[50] Fleet vehicle data provided by R. L. Polk & Co., 2013.
[51] NTD Date, "TS2.2 - Service Data and Operating Expenses Time-Series by System", http://www.ntdprogram.gov/ntdprogram/data.htm, December 2011.
[52] CCAT; "Connecticut Hydrogen and Fuel Cell Deployment Transportation Strategy: 2011-2015;" http://chfcc.org/Publications/Secure%20Reports/PRELIMINARY%20STATUS%20AND%20DIRECTION%20FC%202010%209-20-2010_secure.pdf; September 2010.

public bus routes in California. Fuel economy performance levels for the fuel cell powered buses average 6.8 mi/DGE (diesel gallon equivalent).[53]

Specialty Vehicles

Table 8 – FC Material Handler Advantages
• 1.5 times lower maintenance costs
• 8 times lower refueling/recharging costs
• 2 times lower net present value (NPV) and
• Zero emissions

Specialty vehicles, such as material handling equipment, airport tugs, street sweepers and wheel loaders, are used by a variety of industries, including manufacturing, construction, mining, agriculture, food, retailers, and wholesalers. Batteries that currently power some equipment for indoor use are heavy and take up significant storage space while only providing up to six (6) hours of run time. Fuel cell powered equipment has zero emissions, can be operated indoors, may last more than twice as long (12-14 hours) before refueling, can be refueled quickly, and eliminates the need for battery storage and charging rooms (see Table 8). Fuel cell powered material handling equipment is already in use at dozens of warehouses, distribution centers, and manufacturing plants in North America.[54] Large corporations that are currently using or planning to use fuel cell powered material handling equipment include CVS, Coca-Cola, BMW, Central Grocers, and Wal-Mart.[55]

Hydrogen Infrastructure

Hydrogen refueling stations will be required to support FCEVs including FCEV fleets, buses, material handling equipment, etc. Hydrogen refueling can be developed privately or publically depending on usage. While costs for hydrogen refueling infrastructure could range from $1,000,000 - $3,000,000 per station, it is possible that construction of these stations could be backed by private sector financing or developed publically in conjunction with high efficiency ZEV fleets. H_2USA and NESCAUM are currently developing hydrogen infrastructure models for financing and development to serve projected FCEV fleets (See Appendix III – Eight (8) State Projections for FCEVs). Potential sites for development include existing refueling stations, but new potential sites are also possible.[56, 57, 58, 59, 60] Proton OnSite is associated with Lumber Liquidators and has indicated a willingness to develop hydrogen refueling infrastructure on Lumber Liquidators sites.[61]

HYDROGEN TRANSPORTATION GOALS

NEESC recommends a near-term acquisition of at least 477 FCEVs in the state of Connecticut. The deployment of 445 passenger fleet vehicles and 32 transit/ paratransit buses would provide an annual CO_2 emissions reduction of approximately 4,194 to 7,330 tons per year. The direct acquisition by lease or purchase of 40 FCEVs for the State of Connecticut fleet is also recommended. Additionally, NEESC has

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[53] NREL; "Fuel Cell Buses in U.S. Transit Fleets: current Status 2013," page vi; http://www.afdc.energy.gov/uploads/publication/60490.pdf; December 2013.
[54] DOE EERE, "Early Markets: Fuel Cells for Material Handling Equipment", www1.eere.energy.gov/hydrogenandfuelcells/education/pdfs/early_markets_forklifts.pdf, February 2011.
[55] Plug Power, "Plug Power Celebrates Successful year for Company's Manufacturing and Sales Activity," www.plugpower.com, January 4, 2011.
[56] There are approximately 1,500 retail fueling stations in Connecticut; however, only 59 public and/or private stations within the state provide alternative fuels, such as biodiesel, compressed natural gas, propane, and/or electricity for alternative-fueled vehicles. There are also at least 33 refueling stations owned and operated by Connecticut's Department of Transportation (CTDOT) that could help facilitate the deployment of FCEVs within the state.
[57] "Public retail gasoline stations" www.afdc.energy.gov/afdc/data/docs/gasoline_stations_state.xls, May 5, 2011.
[58] Alternative Fuels Data Center, http://www.afdc.energy.gov/afdc/locator/stations/.
[59] Hyride, "About the fueling station", http://www.hyride.org/html-about_hyride/About_Fueling.html.
[60] Currently, there are five (5) existing/planned fueling stations where hydrogen is provided as an alternative fuel in Connecticut.
[61] There are currently Lumber Liquidator sites located in Danbury, Hartford, North Haven, Norwalk, Waterbury and Waterford, Connecticut.

set a goal for the immediate development of 4-5 hydrogen refueling stations, to support FCEV deployment.

Transformation requires vision, commitment, and action to overcome challenges associated with the deployment of FCEVs and the construction of supporting hydrogen infrastructure. Consumer incentives to mitigate costs and enhance the FCEV ownership experience may include purchasing of state passenger vehicles, "point-of-purchase" rebates, hydrogen fuel rebates, incentives for refueling infrastructure, FCEV buy back incentives, tax incentives, infrastructure partnerships, and high occupancy vehicle (HOV) lanes/parking (see Table 9). Alternative vehicle infrastructure to support ZEVs will require planning and investment by public and private entities with an explanation of a payback on that investment (Appendix V – State Energy Policy/Incentives for Stationary Fuel Cells and Hydrogen Transportation). As summarized below, a state investment of at least $7.58 million for infrastructure development and vehicle deployment could provide a solid framework to support the goal of 445 passenger vehicles, five (5) hydrogen refueling stations. An additional $16 million (50 percent of $32 million) for 32 transit/paratransit buses is also encouraged.

- ***445 Fuel Cell Electric Passenger Vehicles (40 FCEVs for CT State fleet) - $2.225 million.***[62, 63]
- ***H_2 Infrastructure (5 stations) - $5.36 million (50 percent of capital cost).***[64]
- ***32 Fuel Cell transit/paratransit Buses - $16 million (50 percent cost-share).***[65, 66, 67]

Coordination of hydrogen and fuel cell related plans underway in the Northeast states will lead to market and economic development opportunities. Partnerships between the U.S. DOE, H_2USA, industry OEMs, and the hydrogen industry will increase opportunities for phased infrastructure development with deployment of FCEVs. Supporting DOE and national efforts to develop uniform codes and standards will further strengthen deployment opportunities.

Table 9 – Policy/Incentives for FCEV Deployment
• ZEV Program
• Purchase of State Passenger Vehicles
• "Point-of-Purchase" Rebates
• Fuel/Infrastructure/FCEV Buy Back
• Tax Incentives
• Infrastructure Partnerships
• HOV Lanes/Parking Incentives

[62] California's Clean Vehicle Rebate Project provides up to $5,000 per ZEV. Adoption of this incentive for the deployment goal of 445 passenger FCEVs would result in the given total.

[63] California Air Resources Board; "Clean Vehicle Rebate Projects;" http://www.arb.ca.gov/msprog/aqip/cvrp.htm; August 7, 2014.

[64] The current total per station development expense including pre-construction development, construction, installation, equipment, and shipping expenses in 2014 is $2,145,600. Marianne Mintz, Argonne National Labs; "Employment Impacts of Infrastructure Development for Hydrogen and Fuel Cell Technologies;" http://www.hydrogen.energy.gov/pdfs/review14/an035_mintz_2014_o.pdf; June 17, 2014.

[65] CTTransit: Connecticut's Zero Emission Hydrogen Fuel Cell Bus Program; "How much does a fuel cell bus cost?;" http://fuelcell.cttransit.com/index.php/facts/187-how-much-does-a-fuel-cell-bus-cost; September 28, 2014.

[66] An order for 100 fuel cell buses would reduce the cost to $1 million or less. Although Connecticut 's goal is for 32 buses, the regional goal of 638 buses by 2025 would create an order well over 100 units and would drive each units cost for each bus down to the $1 million target price.

[67] Federal Transit Authority (FTA), National Fuel Cell Bus Program (NFCBP); "FTA Fuel Cell Bus Research: Research Accomplishments Through 2011;" http://www.fta.dot.gov/documents/FTA_Report_No._0014.pdf; page 2; March 2012.

CONCLUSION

Hydrogen and fuel cell technology provides significant opportunities for more efficient use of cleaner energy, job creation and economic development. Realizing over $604.34 million in revenue and investment in 2011, the hydrogen and fuel cell industry in Connecticut is estimated to have contributed approximately $22 million in state and local tax revenue, and over $211.65 million in gross state product annually (for 2011). Additionally, eight (8) of these companies are OEMs of hydrogen and/or fuel cell systems, and were responsible for supplying 1,010 direct jobs and $311.65 million in direct revenue and investment in 2011. Currently, there are at least 600 Connecticut companies that are part of the growing hydrogen and fuel cell industry supply chain in the Northeast region. If newer/emerging hydrogen and fuel cell technology were to gain momentum, the number of companies and employment for the industry could grow substantially.

Hydrogen and fuel cell technology provides an opportunity for Connecticut to more fully utilize its renewable energy industry using hydrogen and fuel cells for transportation, energy storage, and use at consumer sites. Such use could make Connecticut a showcase for renewable energy while reducing GHG emissions as new jobs are created. This configuration will also increase local end user reliability which is of high value for businesses and industry, and will be cleaner with less GHG emissions. To facilitate the execution of this plan Connecticut will need to develop an "Action Plan," providing provisions for funding and financing and a schedule for goal implementation and work responsibilities. The goals recommended by NEESC include:

- **131 to 175 MW fuel cell electric generation by 2025**
- **477 FCEVs (445 [40 FCEVs for CT State fleet] passenger and 32 transit/paratransit buses) as zero emission vehicles (ZEV)**
- **4 to 5 hydrogen refueling stations (to support FCEV deployment)**

These goals represent a short-term investment for long-term productivity. As such, the Action Plan and schedule should recognize the short-term impact of public support, provide expectation(s) for long-term productivity, and assist with the development of public/private partnership(s) necessary to share risk and facilitate long-term market opportunities.

APPENDICES

APPENDIX I – Figure I

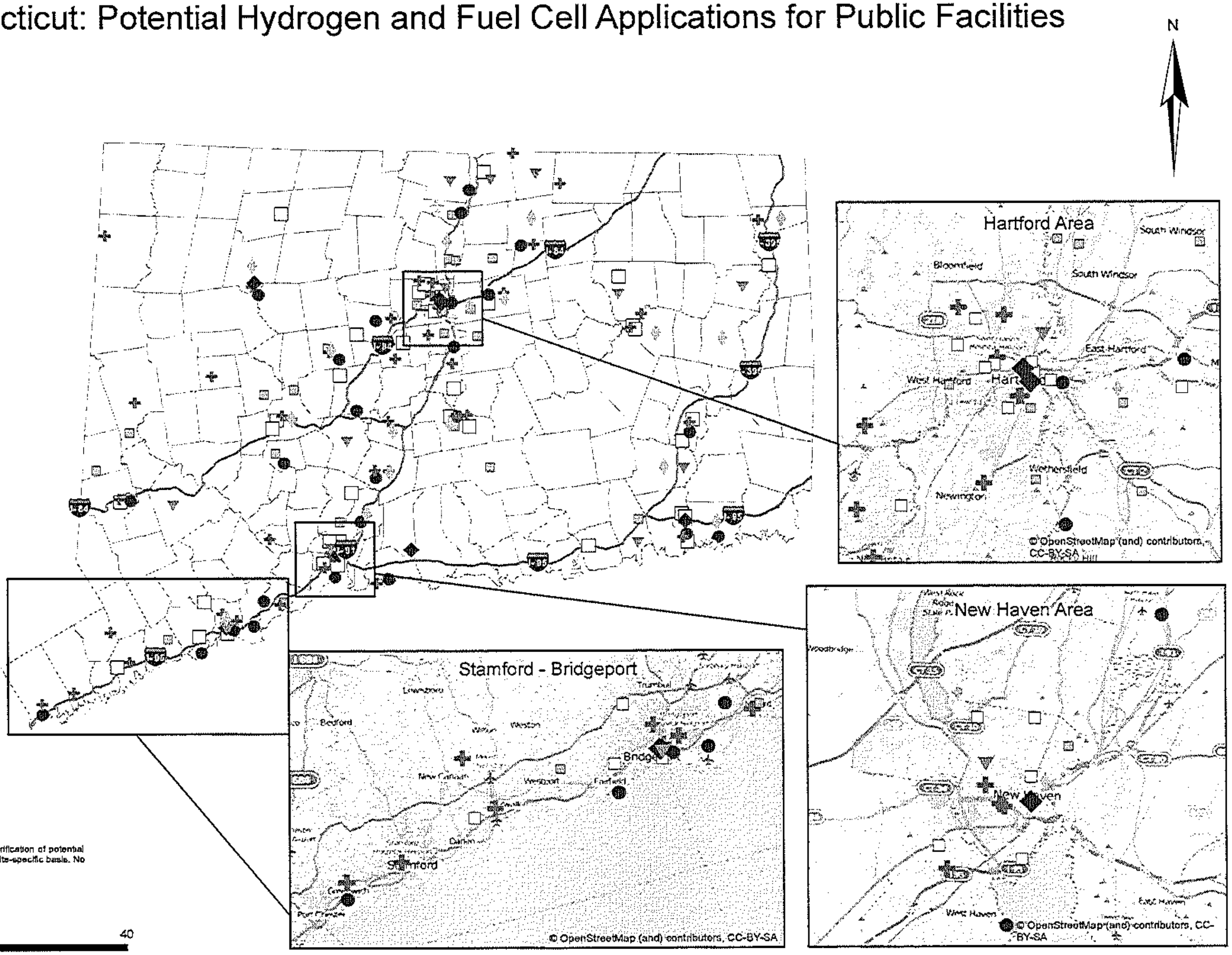
Connecticut: Potential Hydrogen and Fuel Cell Applications for Public Facilities

Legend

- Landfills
- Correctional Facility
- Federally Owned Building
- Hospitals
- Military Airports
- Military Base
- Wastewater Treatment Plants (ADF<10 mgd)
- Public Schools (With CHP Potential[1])
- Colleges
- Interstate
- Area Not Served with Natural Gas
- Area Served by Natural Gas

Northeast Electrochemical energy storage Cluster

Produced with support provided by the U.S. SBA



Sources:
U.S. Census Bureau
U.S. General Services Administration
U.S. Environmental Protection Agency
OpenStreetMap
HighSchools.com
ReferenceUSA
usamilitarybenefits.com
Federal Aviation Administration
www.usamilitarybenefits.com
Northeast Gas Association

Footnotes:
1) Public schools with combined heat and power potential indicate public schools that house swimming pools.

Disclaimer:
Information presented in this map is for planning purposes only. Verification of potential sites and their energy consumption has not been undertaken on a site-specific basis. No representation as to the accuracy of the data depicted is implied.

0 20 40
Miles

January, 2015

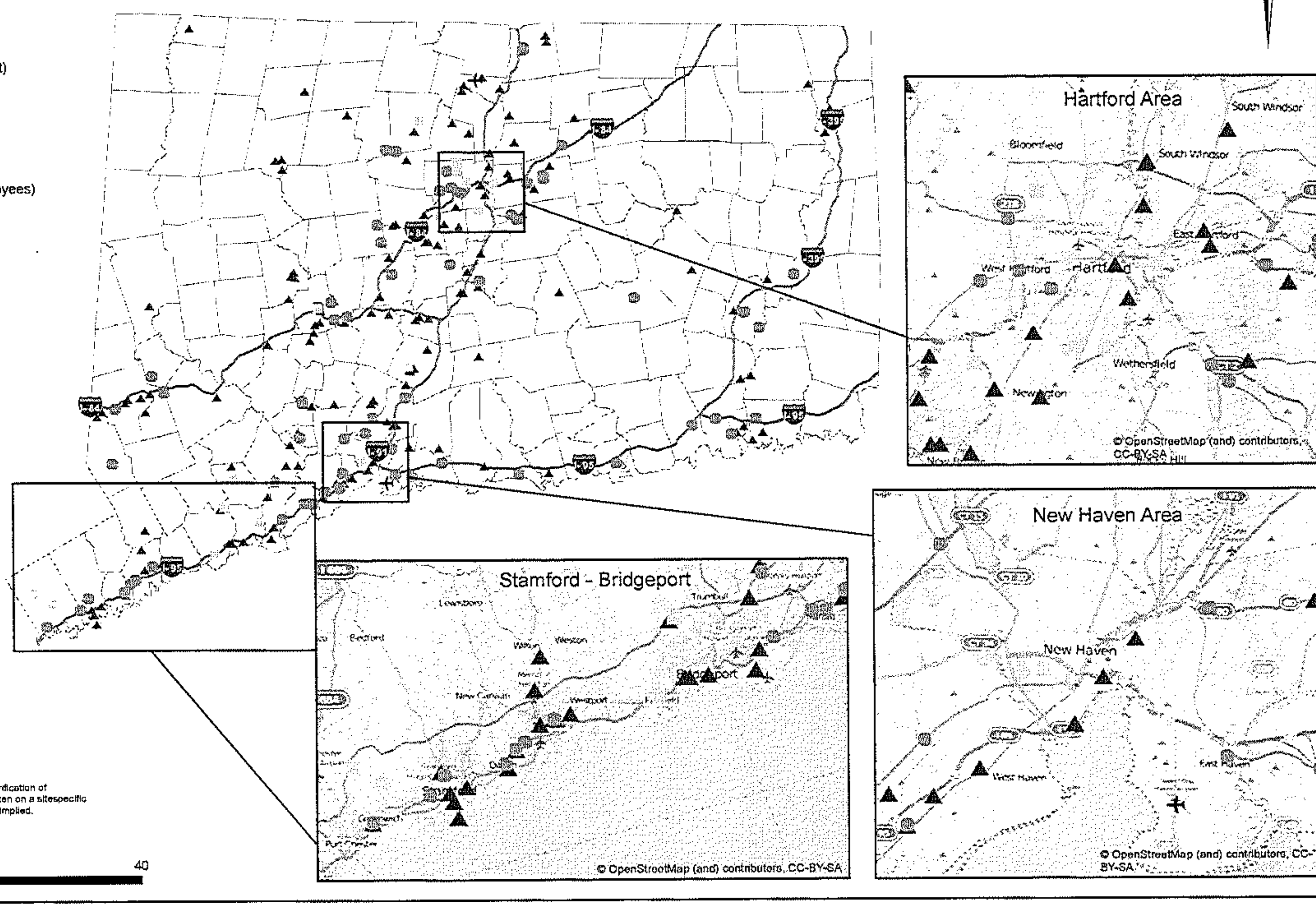
APPENDIX I – Figure 2

Connecticut: Potential Hydrogen and Fuel Cell Applications for Private Facilities

N

Legend

- Convalescent Homes (200+ Bed Count)
- Commercial Airports
- Food Sales (150+ Employees)
- Energy Intensive Industry (100+ Employees)
- Interstate
- Area Not Served by Natural Gas
- Area Served by Natural Gas



Northeast Electrochemical energy storage Center

Produced with support provided by the U.S. SBA

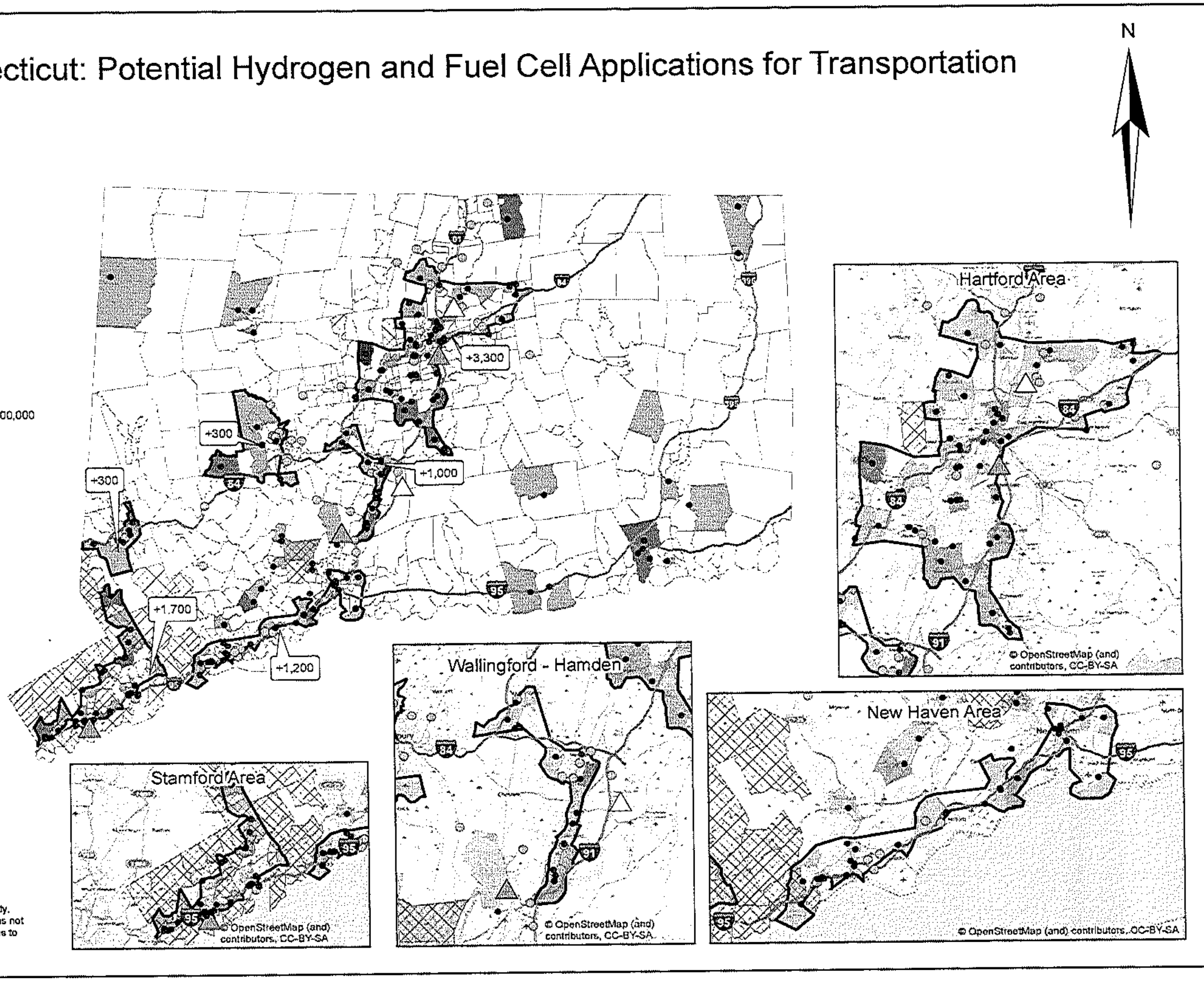
Sources:
U.S. Census Bureau
ReferenceUSA
AssistedLivingList.com
altiusdirectoy.com
Federal Aviation Administration
Northeast Gas Association

Disclaimer
Information presented in this map is for planning purposes only. Verification of potential sites and their energy consumption has not been undertaken on a sitespecific basis. No representation as to the accuracy of the data depicted is implied.

January, 2015

APPENDIX I – Figure 3

Connecticut: Potential Hydrogen and Fuel Cell Applications for Transportation



Legend

H2 Refueling Stations

Status

- Existing
- Planned
- Fleet Owner Locations
- Current Hydrogen Users
- Interstates
- Fleet Clusters (Passenger Vehicles)
- 30% or more of Households with income > $200,000

Total Passenger Fleet Vehicles

- No Data
- 20 - 100
- 101 - 500
- 501 - 1000

Northeast Electrochemical energy storage Cluster

Produced with support provided by the U.S. SBA

Sources:
R. L. Polk & Co.
U.S. Census Bureau
Alternative Fuels Data Center
Electrochemical Hydrogen Separator: Opportunities for Commercialization 2009

The fleet vehicle counts are based on companies with a total of 20 or more passenger vehicles registered within Connecticut. Consequently, companies with less than 20 vehicles are not depicted. Most rental and leased vehicles have been omitted. This map was produced with the cooperation of H2USA and SBA.

Disclaimer:
Information presented in this map is for planning purposes only. Verification of potential sites and their energy consumption has not been undertaken on a site-specific basis. No representation as to the accuracy of the data depicted is implied.

0 10 20
Miles

January, 2015

APPENDIX II - Financing Fuel Cells through C-PACE

Commercial Property Assessed Clean Energy (C-PACE) is an innovative program that provides affordable, long-term financing, reducing out-of-pocket cost to building owners, for smart energy efficiency and clean energy upgrades. Qualifying energy improvement projects, including fuel cells and micro grids, are paid for over time through an additional assessment on the property owner's tax bill. Similar to a sewer tax assessment, capital provided under the C-PACE program is secured by a lien on the property, so low-interest, long-term capital can be raised from the private sector with no government financing required.[68]

Connecticut fuel cell projects in particular can benefit through the use of C-PACE financing to help lower the cost of capital, allowing building owners the ability to compete and reduce their low emissions renewable energy credit (LREC) auction bid prices to between $15 and $45 per REC, thus giving the project a significant competitive advantage (see example below). This also allows Connecticut to achieve its energy objectives for delivering "cleaner, cheaper, and more reliable" sources of energy in-state at an Renewable Portfolio Standard (RPS) cost less than the Alternative Compliance Payment of $55/MWh. It is estimated that 36 MW of installed fuel cell capacity is needed to generate 1% of the RECs required to meet the Connecticut Class I RPS – which is 20% by 2020.

Example of Sensitivities of Net Present Value of Fuel Cell Projects Financed through C-PACE on Avoided Electricity Cost and LREC Incentive[69]

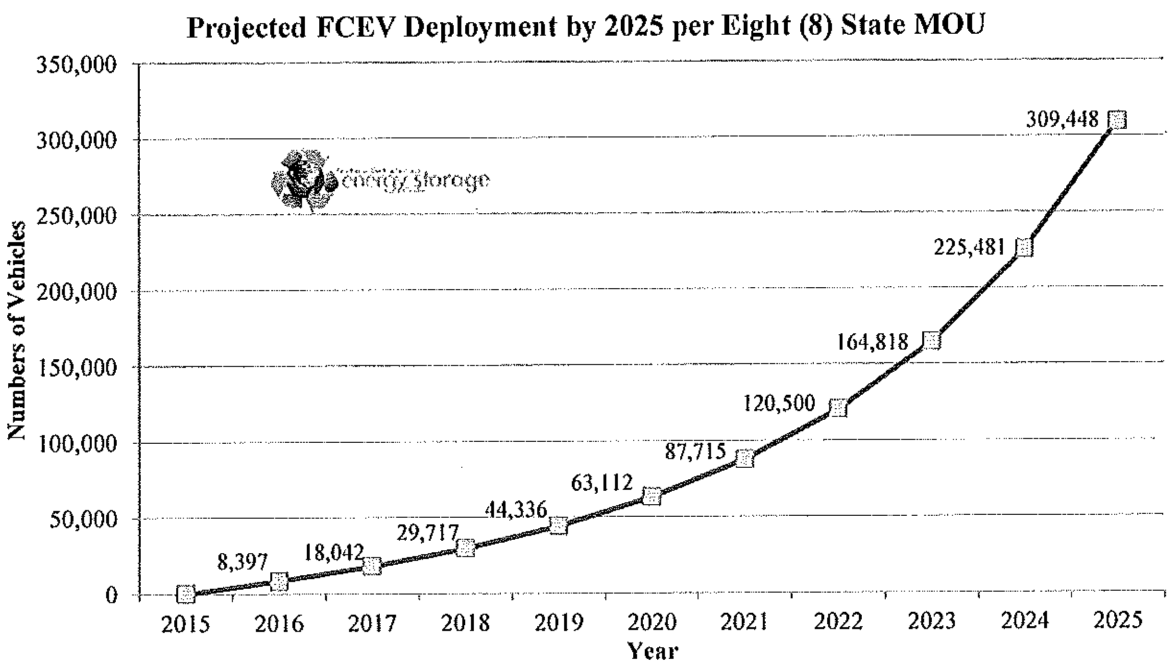
Avoided Electricity Cost ($/kWh)	**LREC Price** ($/MWh)			
	$45	$35	$25	$15
$0.15	$1,015,734	$839,536	$663,388	$487,141
$0.14	$751,780	$575,583	$399,385	$223,188
$0.13	$487,827	$311,630	$135,432	-$40,765
$0.12	$223,874	$47,677	-$128,531	-$304,719

[68] Learn more about C-PACE and apply online at www.c-pace.com.

[69] Assumptions include: installed cost of $7/W, thermal utilization of 55%, capacity factor of 85%, natural gas price of $9/MMBtu, system life of 20 years, financing term of 20 years, interest rate of 6%, and ITC and MACRS depreciation incentives from the federal government.

APPENDIX III – Eight (8) State MOU Projections for FCEVs[70]

	Eight (8) State MOU			Projections for FCEVs per each MOU State[71]							
	Total Sale Requirements	Total ZEV Sales Requirements	FCEV[72]	CA	CT	MA	NY	RI	VT	OR	MD
2015	0	0	0	0	0	0	0	0	0	0	0
2016	89,543	33,587	8,397	3,595	545	1,008	1,860	167	91	467	662
2017	192,402	72,168	18,042	7,725	1,172	2,167	3,998	360	195	1,003	1,423
2018	316,902	118,866	29,717	12,724	1,930	3,569	6,584	592	321	1,652	2,344
2019	472,806	177,344	44,336	18,984	2,879	5,325	9,824	883	479	2,465	3,497
2020	673,031	252,446	63,112	27,023	4,099	7,580	13,984	1,258	682	3,509	4,977
2021	935,407	350,860	87,715	37,558	5,696	10,535	19,435	1,748	948	4,878	6,918
2022	1,285,032	482,001	120,500	51,596	7,826	14,472	26,699	2,401	1,302	6,701	9,503
2023	1,757,645	659,272	164,818	70,572	10,704	19,795	36,519	3,284	1,781	9,165	12,998
2024	2,404,566	901,925	225,481	96,547	14,643	27,081	49,960	4,493	2,436	12,538	17,782
2025	**3,300,000**[73]	1,237,792[74 75]	309,448	132,500	20,096	37,165	68,565	6,166	3,344	17,208	24,404



[70] Data provided is an averaged projection that does not account for different market drivers and/or incentives/barriers that could substantially change the deployment ratios between state and the delivery of different ZEV/hybrid vehicles.

[71] Derived from applying 4.675 percent to FCEVs. The 4.675 percent was calculated by comparing 8-State MOU data to 2011 registered vehicles by state. This data assumes 25 percent of all ZEVs (FCEVs and BEVs) will be FCEVs.

[72] This data assumes 25 percent of all ZEVs (FCEVs and BEVs) will be FCEVs.

[73] California Environmental Protection Agency Air Resources Board; http://www.arb.ca.gov/newsrel/newsrelease.php?id=620; October 24, 2013.

[74] Derived from a DOE projection of California ZEV (FCEV and BEV), California transitional ZEV (plug-in hybrids), and California total sales (ZEV and transitional). These projections were applied to the other seven (7) states' 2011 registered vehicle data to estimate potential ZEV vehicle requirements.

[75] DOE EERE; "Fact #771 March 18, 2013 California Zero-Emission Vehicle Mandate is Now in Effect; https://www.dropbox.com/s/jrl4gbzgw7tsy5p/Fact%20%23771%20%20March%2018%2C%202013%20California%20Zero-Emission%20Vehicle%20Mandate%20is%20Now%20in%20Effec.pdf?dl=0.

APPENDIX IV – Connecticut SWOT Analysis

Environment factors internal/external to Connecticut's existing hydrogen and fuel cell industry are provided below in the form of an economic strengths, weaknesses, opportunities and threats (SWOT) assessment. The SWOT analysis provides information helpful in matching the industry's resources and capabilities to the competitive environment in which it operates.[76]

Strengths

- *Stationary Power* – Strong supply chain.
- *Transportation Power* – Strong market drivers (ZEV)
- *Economic Development Factors* – Supportive state policies.

Weaknesses

- *Stationary Power* – Cost/Performance improvement required.
- *Transportation Power* – Hydrogen infrastructure build out needed.
- *Portable Power* – Limited/No commercial participation.
- *Economic Development Factors* – Limited industry growth.

Opportunities

- *Stationary Power* – Global sales for grid and industry applications.
- *Transportation Power* – Air emission compliance.
- *Portable Power* – Alternative to batteries.
- *Economic Development Factors* – Job creation.

Threats

- *Stationary Power* – Other renewable energy technologies.
- *Transportation Power* – Continued use of less efficient conventional technologies.
- *Economic Development Factors* – Losing industry to foreign companies.

[76] QuickMBA; "SWOT Analysis;" http://www.quickmba.com/strategy/swot/; February 2014

APPENDIX V – State Energy Policy/Incentives for Stationary Fuel Cell and Hydrogen Transportation

	ME	NH	VT		RI	CT	NY	NJ
State Energy Policy/Incentives for Stationary Fuel Cells								
Mandatory Renewable Portfolio Standard (RPS)								
Net Metering								
Public Benefits Fund								
Performance-Based Power Purchase								
Utility Ownership/Investment								
State Grant Program								
State Loan Programs								
Microgrid Reliability Program								
Property Tax Incentive (Commercial)								
Sales Tax Incentive								
Property-Assessed Clean Energy (PACE) Financing								
One Stop Regulatory Approval								
Identified State "Point" Person								
State Energy Policy/Incentives for Hydrogen Transportation								
	ME	NH	VT		RI	CT	NY	NJ
Zero Emission Vehicle (ZEV) Program (FCEV/H_2 Infrastructure)								
ZEV Purchase Target for State Government Fleets (TBD)								
Purchase Incentives/"Point-of-Purchase" Rebates								
Fuel Incentives								
Public/Private Infrastructure Partnership								
Fuel Efficiency Standard (Private/State Fleets)								
Refueling Infrastructure Incentives								
REC Available for Renewable H_2								
Tax Incentives								
HOV Lanes and Parking Incentives								
One Stop Regulatory Approval								
Identified State "Point" Person								
NEESC Development Plan Goals								
	ME	NH	VT		RI	CT	NY	NJ
Stationary Fuel Cell (MW, low/high range)	54/73	45/61	15/20	234/312	37/49	131/175	543/724	254/339
Transportation FCEV (near-term number of vehicles)	80	21	80	1,818	142	445	2,803	5,455
Transportation Fuel Cell Electric Bus (near-term number of vehicles)	3	4	2	49	11	32	364	173
Refueling Stations (low/high range)	1/2	1/2	1/2	18/19	2/3	4/5	27/32	55/60

Eligible

Eligible if Renewable

APPENDIX VI – Summary of Potential Fuel Cell Applications

Hydrogen and fuel cell technologies offer significant opportunities for improved energy reliability, energy efficiency, and emission reductions. Large fuel cell units (≥300 kW) may be appropriate for applications that serve the grid and large electric and thermal loads at consumer sites. Smaller fuel cell units (< 300 kW) may provide back-up power for telecommunication sites, restaurants/fast food outlets, and smaller sized public facilities.

Category	Total Sites	Potential Sites	FCs < 299 kW (#)	FCs 299 - 999 kW (#)	FCs >/=1,000 kW (#)
Stationary Targets					
Education	1,701	265[77]	247	7	11
Food Sales	4,000+	104[78]		63	41
Food Services	5,000+	500[79]	500		
Inpatient Healthcare	372	31[80]		27	4
Lodging	543	104[81]		102	2
Public Order & Safety	209	33[82]		33	
Energy Intensive Industries	541	126[83]		143	28
Government Operated Buildings	88	7[84]		7	
Wireless Telecommunication Towers	301[85]	30[86]	30		
WWTPs	77	4[87]		3	1
Landfills	23	2[88]		2	
Airports (w/ AASF)	53	3 (3) [89]			3
Military	1	1			1
Ports	13	3		3	
Total Stationary	**12,921**	**1,213**	**777**	**345**	**91**

CBECS Data

[77] 265 high schools and/or college and universities located in communities serviced by natural gas with 10+ buildings may satisfy a 300+ kW unit and locations with 33+ buildings may satisfy a 1000+ kW unit. On average, educational facilities consume 283,000 kWh of electricity per building on an annual basis.

[78] 104 food sales facilities located in communities serviced by natural gas and have 60+ employees may satisfy a 300+ kW unit and locations with 200+ employees may satisfy a 1000+ kW unit. On average, food sales facilities consume 43,000 kWh of electricity per employee on an annual basis.

[79] Ten percent of the 5,000 food service facilities located in communities serviced by natural gas. On average, food services facilities consume 20,300 kWh of electricity per work on an annual basis, which results in more than 130 workers required to satisfy a 300+ kW unit and locations with 390+ employees may satisfy a 1000 kW unit. A smaller fuel cell may be more appropriate to meet hot water and space heating requirements.

[80] 31 Hospitals located in communities serviced by natural gas and manage 100+ beds may satisfy a 300+ kW unit or 350+ beds may satisfy a 1000+ kW unit.

[81] 64 hotel facilities with 94+ employees and 40 convalescent homes with 150+ beds onsite, which are located in communities serviced by natural gas. 2 of these hotels/convalescent homes employ 329+ employees or occupy 525+ beds and therefore are not large enough to satisfy a 1000+ kW unit. On average, lodging facilities consume 28,000 kWh of electricity per worker on an annual basis.

[82] Correctional facilities and/or other public order and safety facilities with 212 workers or more. On average, public order and safety facilities consume 12,400 kWh of electricity per worker on an annual basis.

[83] On average, energy intensive industry facilities consume 21,500 kWh of electricity per employee on an annual basis. Locations located in areas serviced by natural gas with 122+ employees may satisfy a 300+ kW unit and 427+ employees may satisfy a 1000+ kW unit.

[84] Seven actively owned federal government operated building located in communities serviced by natural gas.

[85] The Federal Communications Commission regulates interstate and international communications by radio, television, wire, satellite and cable in all 50 states, the District of Columbia and U.S. territories.

[86] Ten percent of the 301 wireless telecommunication sites in Connecticut targeted for back-up PEM fuel cell deployment.

[87] Connecticut WWTP with average flows of 3.0+ MGD may satisfy a 300+ kW unit. Locations with 10.5+ MGD flows may satisfy a 1000+ kW unit. A conservative 10 percent were used as potential targets.

[88] Ten percent of the landfills targeted based on LMOP data.

[89] Airport facilities with 2,500+ annual Enplanement Counts, located in areas serviced by natural gas. Locations supporting AASF may consider installation of a 1000+ unit.

As shown above, the analysis provided here estimates that there are approximately 1,213 potential locations, which may be favorable candidates for the application of a fuel cell to provide heat and power. Assuming the demand for electricity was uniform throughout the year, approximately 436 fuel cell units, with a capacity of at least 300 – 400 kW, could be deployed for a total fuel cell capacity of 131 to 175 MW.[90]

Category	Total Units	Potential Targets	CO_2 Emissions (Tons/Year)
Transportation Targets			
FCEVs	9,506	445	**2,113.75**
Transit Buses	670	32	**2,080 to 5,216**
Retail Refueling Stations	1,500	5	**NA**

As shown above, FCEV replacements for existing Connecticut fleet vehicles could start with at least 477 vehicles, providing annual CO_2 emissions reduction of approximately 4,194 to 7,330 tons per year.

[90] 400 kW units provide a maximum of 1,211,070 MWh electric and 5.399 million MMBTUs (equivalent to 1.58 million MWh) of thermal energy annually, which could reduce CO_2 emissions by at least 368,165 tons per year. 300 kW units provide a minimum of 912,135 MWh electric and 2.21 million MMBTUs annually (equivalent to 648,556 MWh) of thermal energy, which could reduce CO_2 emissions by at least 277,289 tons per year.

APPENDIX VII – Installed Stationary Fuel Cells in Connecticut

Title	Number of Units	Total	Size	City	State	Year	Operational
777 Main St.	1	400	kW	Hartford	Connecticut	2015	Yes
Western Connecticut State University (WCSU)	1	400	kW	Danbury	Connecticut	2013	Yes
Dominion Fuel Cell Generating Facility	5	14,900	kW	Bridgeport	Connecticut	2013	Yes
Hartford Hospital	1	1,400	kW	Hartford	Connecticut	2013	Yes
Macy's Fulfillment Center	3	600	kW	Cheshire	Connecticut	2013	Yes
University of Connecticut, Depot Campus	1	400	kW	Mansfield	Connecticut	2012	Yes
Eastern Connecticut State University Science Building	1	400	kW	Willimantic	Connecticut	2012	Yes
St. Francis Hospital	1	400	kW	Hartford	Connecticut	2012	Yes
City Hall and Hall of Records	1	400	kW	New Haven	Connecticut	2012	Yes
Doosan Fuel Cells America	1	400	kW	South Windsor	Connecticut	2011	Yes
Coca-Cola Refreshments Bottling Plant	2	800	kW	East Hartford	Connecticut	2011	Yes
Carla's Pasta	1	300	kW	South Windsor	Connecticut	2011	Yes
Hamden High School	1	400	kW	Hamden	Connecticut	2011	Yes
Whole Foods Market	1	400	kW	Fairfield	Connecticut	2011	Yes
Central Connecticut State University	1	1,400	kW	New Britain	Connecticut	2011	Yes
Stop & Shop	1	400	kW	Torrington	Connecticut	2010	Yes
360 State Street	1	400	kW	New Haven	Connecticut	2010	Yes
New Haven Schools	1	400	kW	New Haven	Connecticut	2010	Yes
Pratt & Whitney	2	800	kW	Middletown	Connecticut	2010	Yes
Connecticut Science Center	1	200	kW	Hartford	Connecticut	2009	Yes
Hartford Life	1	300	kW	Windsor	Connecticut	2009	Yes
Whole Foods Market	1	200	kW	Glastonbury	Connecticut	2008	Yes
Cabela's Sporting Goods	4	800	kW	East Hartford	Connecticut	2008	Yes
Middletown High School	1	200	kW	Middletown	Connecticut	2008	Yes
Eastern Connecticut State University central heating plant	1	400	kW	Willimantic	Connecticut	2006	Yes
Pepperidge Farm Bakery	2	1,300	kW	Bloomfield	Connecticut	2005	Yes
Fairfield Water Pollution Control Authority	1	200	kW	Fairfield	Connecticut	2005	Yes
	39	**28,600**	**kW**				